

Clinical Evaluation of Irreversible Compression of Ultrasound Images Using the JPEG Algorithm at Approximately 9:1

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A PRIOR ULTRASOUND compression study performed by our group considered a variety of factors, including frame-grabbed versus direct Digital Imaging and Communications in Medicine (DICOM) acquisition techniques, Joint Photographic Expert's Group (JPEG), and wavelet compression algorithms, the presence of "burned-in" text in the image, and a variety of compression ratios ranging from 10:1 to 25:1.¹ The results of this prior study showed that grayscale ultrasound images compressed with the JPEG algorithm were preferable to those compressed with our wavelet techniques. The results also indicated that grayscale ultrasound images compressed with a quality factor of 70 (corresponding to a compression ratio of approximately 9:1) were of acceptable for diagnostic purposes. The purpose of this study was to formally validate that preliminary finding using a large number of grayscale and color ultrasound images.

METHODS

A frame-grabbed ultrasound image was selected from each of 300 patients by two of the authors (J.W.C. and E.M.J.) during the course of their routine clinical practice. These images were evenly distributed among four general anatomical regions (abdomen, pelvis, small parts, and vascular). A total of 36 of the 300 images were color. The images were processed on a PC using a commercial JPEG implementation. The quality factor was held fixed at values of 70 and 97 for the grayscale and color images, respectively. This resulted in compression ratios ranging from 6 to 13, with an average value of approximately 9:1. The images were then sent to a picture archiving and communication system (PACS) workstation via DICOM for evaluation. Tables 1 and 2 show a summary of the number of images, type of images, and resultant compression ratio range for this study.

The images were presented as original/compressed pairs on a single cathode ray tube (CRT) monitor in a blinded fashion to a group of five radiologists practicing in three different departments. Radiologists were asked to pick which image (right or left) was preferred in terms of diagnostic utility, and to weight their preference from 1 to 5 (1 = slight preference, 5 = strong preference). The original image appeared on the right randomly in 50% of the cases. Care was taken to keep the CRT luminance and ambient light in tight control during all reading sessions.

The data from all five radiologists were pooled and the rates at which the original and compressed images were preferred was computed. The number of image pairs and radiologist readings were chosen to assure that the 95% confidence intervals of the preference rates were approximately 2.5%. The number of data

Table 1. Summary of Image Type, Number, and Compression Ratio for Grayscale Ultrasound Images

Variable	Abdomen	Pelvis	Small Parts	Vascular
No. of grayscale images	74	74	73	43
Maximum compression ratio (QF = 70)	12.3	12.8	11.2	11.6
Minimum compression ratio (QF = 70)	6.0	7.2	7.1	6.6
Average compression ratio (QF = 70)	8.6	9.3	9.1	8.4

NOTE. Grayscale images were compressed using the JPEG algorithm at a quality factor (QF) of 70. This resulted in compression ratios ranging from 6.0 to 12.8 with an average of approximately 9 to 1.

points also assured that if the preference rate of either the compressed or the original images was 45% or less, this would be detected using our experimental design 90% of the time.

RESULTS

Table 3 shows a summary of the radiologist's evaluation. The original image was preferred $50.1\% \pm 1.3\%$ of the time and the compressed image was preferred $49.9\% \pm 1.3\%$ of the time, indicating statistically equivalent diagnostic utility for the compressed and original ultrasound images used in this study.

DISCUSSION AND CONCLUSIONS

Lossy JPEG compression techniques are not "bit-preserving." Some of the original information is lost in favor of effectively compressing the image for purposes of more efficient transmission or storage. The results of this study indicated that color and grayscale ultrasound images compressed with JPEG at approximately 9:1 were indistinguishable from the originals for primary diagnostic purposes. Because it is supported by the DICOM

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Table 2. Summary of Image Type, Number, and Compression Ratio for Color Ultrasound Images

Variable	Abdomen	Pelvis	Small Parts	Vascular
No. of color images	1	1	2	32
Maximum compression ratio (QF = 97)	8.2	8.6	9.1	10.9
Minimum compression ratio (QF = 97)	8.2	8.6	8.2	7.9
Average compression ratio (QF = 97)	8.2	8.6	8.7	9.3

NOTE. Color images were compressed using the JPEG algorithm at a quality factor (QF) of 97. This resulted in compression ratios ranging from 8.2 to 10.9 with an average of approximately 9 to 1.

standard, images compressed with the JPEG baseline standard can be stored by and sent to conforming DICOM devices, making it possible to use lossy compression for primary diagnostic purposes on standards-based PACS.

One important caveat regarding our study and findings involves the display device and mode we employed. We presented the images on a color CRT monitor in a manner consistent with the clinical practice. Since zoom tools were rarely used when interpreting ultrasound cases on the PACS, they were not used by radiologists during the study viewing sessions. It is possible that if zoom tools (or a higher fidelity display device) were used, subtle differences between the original and com-

Table 3. Study Results: Summary of Preferences by Radiologist

Radiologist	Preferred Original	Preferred Decompressed	Preferred Original (weighted)	Preferred Decompressed (weighted)
Radiologist 1	155	145	155	145
Radiologist 2	149	151	298	302
Radiologist 3	149	151	149	151
Radiologist 4	147	153	155	171
Radiologist 5	151	149	151	149
Total	751	749	908	918

NOTE. Radiologists were asked to pick which image (right or left) was preferred in terms of diagnostic utility, and to weight their preference from 1 to 5 (1 = slight preference, 5 = strong preference). Each radiologist viewed 300 pairs of images. The "preferred original" and "preferred decompressed" columns show how many times (out of 300) each radiologist selected the original or the decompressed image. The "weighted" results show the same information, taking into account the degree of preference (1 through 5) that the radiologist indicated in each selection.

pressed images might be seen. Our results suggest that these observed differences would not be important clinically; however, they may affect radiologist preference and confidence in the compressed images.

REFERENCES

1. Persons KR, Palisson PM, Manduca A, et al: JPEG/wavelet ultrasound compression study. Proc SPIE 3662:232-248, 1999